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THE EFFECTS OF NORMAN WELLS CRUDE OIL ON THE ZOOBENTHOS OF A NORTHERN YUKON STREAM ONE YEAR AFTER AN EXPERIMENTAL SPILL

by

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FISHERIES AND MARINE SERVICE
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This is the sixty-seventh
Technical Report from the
Research and Development Directorate
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Winnipeg, Manitoba

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ABSTRACT

Snow, N. B., D. M. Rosenberg, and J. Moenig. 1975. The Effects of Norman Wells Crude Oil on the Zoobenthos of a Northern Yukon Stream One Year After an Experimental Spill. Fish. Mar. Serv. Res. Dev. Tech. Rep. 550: 8 pp.

The effect of 250 liters of Norman Wells crude oil on selected physical, chemical and biotic parameters of a flowing water system (a tributary of Caribou Bar Creek) in the Northern Yukon, have been monitored for a period of one year following the experimental spill of 16 August, 1972.

The oil was pumped onto the water surface whereupon it formed an emulsion which was distributed throughout the water column. This produced an initial effect of a catastrophic increase in zoobenthic drift resulting in a 33% reduction of zoobenthos in the stream-bed of the area affected by the oil. Oil was still present in the sediments one month later, by which time there was some evidence of recolonization by zoobenthic organisms.

There have been no significant changes noted in the physical and chemical characteristics of that section of the creek nor was any oil found in the sediments one year after the experimental spill. The zoobenthos standing crop of that same section of the creek had increased in abundance but not in diversity over the same period of time. Increases of the same proportion were recorded at all stations along the length of the creek during the open-water season of 1973 and the increase in the oil spill section is therefore not considered to be attributable to the effect of oil.

The emergence of adult members of the dominant zoobenthic fauna (Chironomidae and Simuliidae) produced the observed changes in zoobenthic standing crop during 1973 when larvae of the latter group were more numerous than in 1972.

The section of the creek which received oil during 1972 appears to have recovered with respect to zoobenthos abundance and diversity in the year following the experimental spill. The 'self-cleansing' propensity of flowing water systems is discussed.

RÉSUMÉ

Snow, N. B., D. M. Rosenberg, and J. Moenig. 1975. The Effects of Norman Wells Crude Oil on the Zoobenthos of a Northern Yukon Stream One Year After an Experimental Spill. Fish. Mar. Serv. Res. Dev. Tech. Rep. 550: 8 pp.

À la suite d'un déversement expérimental de 250 litres de pétrole brut de Norman Wells, le 16 août 1972, on a observé durant un an les effects de l'huile sur un choix de paramètres physiques, chimiques et biologiques d'un système de cours d'eau tributaire de la crique Caribou Bar dans le nord du Yukon.

On a versé l'huile sur la surface l'eau où elle a formé une émulsion qui s'est répandue dans l'eau. L'augmentation considérable de déplacement zoobenthique qui en a d'abord résulté a réduit de 33% le zoobenthos dans le lit du ruisseau du secteur altéré par l'huile. Un mois plus tard, on trouvait encore de l'huile dans les sédiments; cependant, on y découvrait aussi des preuves de recolonisation des organismes zoobenthiques.

On n'a constaté aucun changement d'importance dans les caractéristiques physiques et chimiques de ce secteur de la crique et, un an après l'experiénce du déversement, on ne retrouvait aucune trace d'huile dans les sédiments. Durant l'année, au même endroit de la crique, la récolte sur pied du zoobenthos avait augmenté en quantité mais non en variété. Après le dégel de 1973, des augmentations proportionnelles ont été notées à toutes les stations le long de la crique et, par conséquent, on n'attribue pas aux effets de l'huile la croissance des organismes en question dans le secteur expérimental.

L'émergence de membres adultes de la faune zoobenthique principale (Chironomidés et Simuliidés) a causé les changements observés au cours de l'année 1973 alors que les larves du dernier groupe étaient plus nombreuses qu'en 1972.

En 1973, année qui a suivi l'expérience, le secteur de la crique sur lequel on avait déversé de l'huile a recouvré son abondance et sa variété de zoobenthos. Le rapport étudie également la tendance des systèmes d'eau courante à se purifier par eux-mêmes.

INTRODUCTION*

The problem of oil-pollution in marine aquatic habitats has been the subject of several reviews (e.g. Nelson-Smith, 1970). The toxicity of crude-oil and various constituent fractions has also received considerable attention (Baker, 1971; Hutchinson et al., 1972; Ottway, 1971; Snow and Rosenberg, 1975). There are, however, so few well-documented studies of the effects of oil pollution on freshwater habitats, that Wilbur (1969) was prompted to state that any extended discussion of the subject would be futile.

In more recent years there has been an increase in the number of incidents involving the introduction of oil products into bodies of freshwater and some of these have received considerable attention (Bugbee and Walter, 1972; Bury, 1972; USEPA, 1973). The effects of such products on flowing waters have been variable, as have the rates of recovery.

The experimental crude-oil spill on a section of Caribou Bar Creek, Y.T., was intended to study the short and longer term effects of this substance on the zoobenthic biota of the system and to predict its rate of recovery.

Norman Wells crude oil (250 liters) was pumped onto a small tributary of Caribou Bar Creek, Y.T., 16 August, 1972. The oil formed an emulsion with the creek water immediately and was distributed as such throughout the water column. It was not effectively contained by booms downstream from the spill.

The initial effect of the oil was to cause a catastrophic increase in zoobenthic drift which resulted in a 33% reduction of zoobenthos in the stream-bed of the area affected by the oil.

Oil was in evidence in the sediments one month later, by which time there was some evidence of recolonization by zoobenthic organisms.

For detailed site-description, procedures, chronology and initial effects on water quality and biota see Brunskill et al. (1973).

METHODS

Three Surber samples equidistant from shore to shore were taken at approximately monthly intervals during the open water season of 1973 at station #6, Caribou Bar Creek. This station is located in the stretch of tributary which received the oil spilt during the preceding year. Water and sediment samples were taken concurrently for chemical analyses and the physical parameters were also measured routinely at this time. The procedures followed were essentially those described by Brunskill et al. (1973). The Surber samples were pooled and sorted at the field camp as soon as possible after collection, using a 3x illuminated magnifier and binocular microscope.

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* The sixth in a series of 13 technical reports on ecological studies of aquatic systems in the Mackenzie and Porcupine drainages in relation to proposed pipeline and highway developments.

Diversity of zoobenthic organisms was estimated using the modified Shannon-Weaver expression:

$$H_{(s)} = c \, [\log_{10} \frac{N-1}{N} \sum_{R=1}^{S} N_R \log_{10} N_R]$$

where N = total number of individuals (all taxa)
N_R = numbers found in the R taxon

$c = 3.322$ (conversion of $\log_{10}$ to $\log_2$)

and only higher taxon levels were used in this calculation.

RESULTS

The ranges of values for major physical and chemical parameters at station #6, Caribou Bar Creek during the open-water season 1973, are given in Table I. Complete data are presented in Campbell et al. (1975). In general, there are no major differences in these parameters as compared to the pre-spill 1972 data presented in Brunskill et. al. (1973). Furthermore, there are no significant differences in these parameters compared to those obtained at the same time in 1973 at another station further upstream (see Table I for ranges of these parameters during summer, 1973).

The densities of zoobenthos at station #6 are given in Table II, together with the index of diversity ($H_{(s)}$). Data obtained in 1972 are also presented in this table for comparative purposes. Higher densities of zoobenthos were obtained in 1973 compared to those of the preceding year. This was true for all Surber sample data collected at the other five stations on the creek.

Far greater numbers of simuliid larvae were present in 1973, compared to 1972. This is the only really significant difference in the zoobenthic fauna for these two years.

Diversity, as measured by $H_{(s)}$, ranges from 0.960 one month before the spill in 1972, to 1.825 immediately following it. The 1973 values are within this range.

No oil residue was found in the water or sediment of the spill area, nor in any other part of the system. The only oil observed during 1973 was a pool in a back eddy of the Porcupine River, near the confluence of Caribou Bar Creek. This oil was of unknown origin and it is possible that it was flushed out of Caribou Bar Creek.

DISCUSSION

The initial response by the zoobenthic biota to the presence of oil in the creek, was a mass exodus of oil-stressed stream bottom organisms manifest by a large increase in zoobenthic drift. This resulted in a 33% depopulation of zoobenthic standing crop in the oil-affected area as determined by Surber samples. By the end of the open water season of 1972 there was evidence of recolonization of this area, probably as a result of immigrating and colonizing upstream zoobenthic drift (Brunskill et. al. , 1973). Drift studies were not carried out at station #6 during 1973.

One of the significant features of these data (Table II), is the general increase in standing crops of most taxa in 1973 compared to those of 1972. This probably reflects the results of the improved method of sorting used in 1973. It may, however, reflect a real increase in biomass. If this is the case, it is evidence of a larger temporal cycle since increases of the same order were measured at all stations along the length of the creek during 1973.

Major fluctuations in zoobenthos standing crop during both years are probably largely the result of emergences of members of the two numerically dominant taxa: Chironomidae and Simuliidae. Larger numbers of simuliid larvae were present in 1973 compared to 1972. This may have been as a result of the oil spill since these larvae were found to preferentially colonize oil-treated artifical substrates in preference to non-treated controls in a previous experiment (Brunskill et. al., 1973). It is more likely, however, that these numbers represent normal variations in population density since no oil was detected in the substrate at this station during 1973.

Taxon diversity as measured by $H_{(s)}$ is of limited value where such low numbers of taxa are involved and our species identifications are not sufficiently complete to date to allow increased efficacy of this index. It does, however, show that immediately following the spill in 1972, the major change was a decrease in numbers of most taxa which was not accompanied by a decrease in diversity. In addition, the range of $H_{(s)}$ in 1973 is within that of 1972 which indicates that there has probably been little change in the diversity of this section of the creek in the intervening period as the result of oil or any natural changes.

This was not found to be the case in other studies dealing with oil pollution of flowing water systems. McCauley (1966) reported significant changes in zoobenthos diversity and taxon densities in response to Bunker oil pollution at the end of her three year study of Muddy River, Mass. Bugbee and Walter (1972) found gasoline residues and lowered diversity of zoobenthic organisms in Grace Coolidge Creek, S.D. two years following a 20,000 liter aviation gasoline spill.

Similar results to those presented here for Caribou Bar Creek (i.e. an initial catastrophic depletion in numbers of zoobenthic organisms have been reported for diesel fuel spills (Bury, 1972; USEPA, 1973). In the case of the latter report, a partial recovery of the affected area

was apparent six months following the 28,000 liter spill.

It would seem that the amount of oil spilt on the Caribou Bar Creek system had catastrophic effects initially but that within an annual cycle, no major changes were detected in the zoobenthic biota or water chemistry. This indicates that such a system has a "self-cleansing" propensity, but it should be remembered that the spill was of a very small amount of oil (250 liters) and it did not occur in the headwater areas. If the oil pollution were severe and chronic, as in the rivers studied by McCauley (1966) and Meynell (1973), comparably more pronounced and persistent effects would be expected. In these cases oxygen depletion and sediment contamination become significant together with concommittent effects on the stream biota.

The "self-cleansing" ability of Caribou Bar Creek was noted with respect to another form of disturbance, increased suspended sediment load, similar to that which occurred in another arctic stream in Alaska (Nyquist, personal communication). It may be concluded that small-scale disturbances to such streams in their middle or lower reaches may not produce long-lasting or irreversible effects. Dunbar (1973) does not include Arctic flowing water systems in his list of "fragile" habitats.

CONCLUSIONS

The initial effect of the experimental oil spill on a section of Caribou Bar Creek, Y. T., was to cause a large increase in the numbers of drifting zoobenthic organisms and a 33% reduction in the zoobenthos standing crop in that section of the creek.

The zoobenthos standing crop of that same section of creek, one year following the experimental oil spill had increased in abundance but not in diversity. Increases in zoobenthos standing crop at other stations along the length of the creek were of the same proportion and, therefore, the increase in the oil-spill section was not considered to be the effect of oil.

Fluctuations in the zoobenthos standing crop of the oil-spill section resulted from emergence of the dominant fauna, Chironomidae and Simuliidae. Larvae of the latter group were more abundant in the summer of 1973 than in 1972.

No extractable oil was found in the sediment of the oil spill section of the creek one year following the experimental oil-spill.

The oil spill section of the creek appeared to have recovered with respect to zoobenthos density and standing crop in the period of one year following the experimental oil-spill.

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Table I. Ranges of some physical and chemical parameters at station #6, Caribou Bar Creek, June-Sept. 1973.

Temperature	(°C)	8-14
Conductivity	(μmho/cm at 25°C)	19-25.5
pH		6.3-6.8
Alkalinity	(MolesHCO_3/m^3)	0.132-0.224
Dissolved Oxygen	(mg/1)	9.2-10.4
Total dissolved P	(mMoles/m^3)	0.29-0.35
Total dissolved N	(mMoles/m^3)	11.8-31.2
Silica	(mMoles/m^3)	50.8-113.0
SO_4	(Moles/m^3)	0.045-0.060

Table II. Numbers of macrozoobenthos per m^2 estimated from Surber samples taken at station 6, Caribou Bar Creek, before and after the experimental oil spill of August 16, 1972. (- indicates no organisms).

1972	29 June	28 July	12 Aug.	17 Aug.	31 Aug.	14 Sep
Plecoptera	43	32	531	27	247	124
Ephemeroptera	14	219	118	59	5	11
Trichoptera	11	79	57	16	57	5
Chironomidae	326	5836	1151	129	3074	742
Simuliidae	11	68	14	-	7	-
Tipulidae	11	14	25	5	4	27
Ceratopogonidae	-	-	-	-	-	-
Hydracarina	11	488	197	5	337	32
Oligochaeta	-	-	14	-	11	-
Empididae	4	-	-	5	11	5
Total	431	6737	2107	246	3752	946
Diversity Index, $H_{(s)}$	1.463	0.960	1.807	1.825	1.058	1.152

1973	9 June	8 July	2 Aug.	27 Aug.
Plecoptera	43	93	126	126
Ephemeroptera	11	1991	556	118
Trichoptera	183	111	104	122
Chironomidae	1292	4237	3982	2336
Simuliidae	108	5845	111	-
Tipulidae	-	18	25	4
Ceratopogonidae	22	22	11	-
Hydracarina	215	230	237	653
Oligochaeta	-	36	22	32
Empididae	-	4	29	14
Total	1659	12357	4956	2752
Diversity Index, $H_{(s)}$	1.537	1.738	1.335	1.453

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